151758 K.7
1/31/97

FINAL REPORT
BACKFILL MIX DESIGN & COMPATIBILITY
AND
GEOMEMBRANE SEAM EVALUATION
AMERICAN CHEMICAL SERVICE, INC.
NPL SITE

Performed For:

Horizontal Technologies, Inc.
2309 Hancock Bridge parkway
Bape Coral, FL 33990

Performed By:

J&L Testing Company, Inc.
938 S. Central Avenue
Canonsburg, PA 15317

January 31, 1997
96M2059-01

JLT J&L TESTING COMPANY, INC.
GEOTECHNICAL AND GEOSYNTHETICS MATERIALS TESTING AND RESEARCH

January 31, 1997
96M2059-01

Horizontal Technologies
2309 Hancock Bridge Parkway
Cape Coral, FL 33990

Attn: Greg Rawl, P.G.

FINAL REPORT
BACKFILL MIX DESIGN AND COMPATIBILITY
AND
GEOMEMBRANE SEAM EVALUATION
AMERICAN CHEMICAL SERVICE, INC. NPL SITE
GRIFFITH, INDIANA PROJECT

Dear Mr. Rawl:

J&L Testing Company, Inc. (JLT) is pleased to submit this final report of the work performed to prepare a soil-bentonite backfill design mix, evaluate the anticipated performance of a soil-bentonite backfill mix per EPA 9100 test protocols, and perform an integrity evaluation of the proposed geomembrane joint and liner that will be a part of an HDPE barrier wall to be installed in a cutoff trench at the American Chemical Service NPL Site, Griffith, Indiana. Section 1 discusses the scope of work, Section 2 describes the materials of evaluation. Section 3 describes the mix design work, Section 4 describes the compatibility testing performed on the soil-bentonite mix, Section 5 describes the geomembrane test program, and Section 6 presents our evaluation of the laboratory data.

1.0 SCOPE OF WORK

The scope of work for this project was to (1) determine the optimum mix design using on-site soils and imported commercial bentonite to create a backfill material that would exhibit an inplace permeability of $\leq 1 \times 10^{-7}$ cm/sec with on-site water as the permeant, and (2) evaluate the performance of the proposed HDPE geomembrane connection joint system with a hydrophilic joint sealer in a site water environment. Each is discussed in more detail below.

1.1 Backfill Materials

The first phase of work included preparation of potential backfill mixes using on-site soils with varying bentonite contents to determine the optimum mix which would yield a permeability of $\leq 1x10^{-7}$ cm/sec (ASTM D-5084). Once the optimum backfill mix was determined, the mix was repeated to verify its properties and a sample was also subjected to EPA 9100 compatibility testing using site water as the permeant with permeability monitored over a period of time equal to the inflow of at least 3 pore volumes.

1.2 Geomembrane Seam Testing

Three (3) HDPE geomembrane seams were fabricated and fitted with a hydrophilic sealer rod supplied by Horizontal Technologies. These joints were then subjected to the site water and tap water under 5, 10 and 15 psi differential pressures to determine the effectiveness of the seal and the potential leakage rate through joints. The 15 psi pressure equates to approximately 25 feet of water head, which is the pressure the geomembrane joint may be exposed to if the interior of the barrier wall is fully dewatered. A similar joint with rivetted stainless steel stiffening rods and a hydrophilic seal between the rods and geomembrane were also tested to evaluate the seal around the rivets.

2.0 MATERIALS OF EVALUATION

The materials used for this project included the following:

2.1 Site Water

Samples of site water were collected by Foster Wheeler from monitoring wells No. 3 and No. 16 by first purging the well of three (3) pore volumes and then pumping the groundwater into mason jars. Samples of these sealed glass jars labeled as No. 3 and No. 16 were then shiped in coolers with ice packs to JLT for this test program. These jars were kept sealed and refrigerated until they were used. For this test program, a 50:50 mixture of the this site water (as directed by Horizontal Technologies) was prepared for all tests. The mixture was prepared by compositing one (1) quart jar of each water sample for use as the permeant fluid for the EPA 9100 test. Prior to performing the mix designs, one quart of the 50:50 mix was also prepared, packaged and shipped on ice to Ameritest & Research Company, Inc. of Belford Heights, Ohio for analytical testing. The results of these tests are presented in Appendix A. The test parameters for this analysis were supplied by Horizontal Technologies.

2.2 Soil

Twenty-six (26) soil borings were installed in the area of the barrier wall. Soil samples were then composited over the depth of the borings from the sand and clay strategraphic units. Each sand and clay composite was further composited with other boring composites which resulted in one (1) 5-gallon sand and one (1) 5-gallon clay composite. The sand composite sample was shipped to JLT for the test program.

2.3 Geomembrane

Samples of the geomembrane joint elements and a sample of the hydrophilic joint sealer were shipped to JLT from Horizontal Technologies. JLT then had the regional office of National Seal Company (NSC) in Wexford, PA weld 60 mil NSC HDPE geomembrane panels to the joints per USEPA criteria so that appropriate coupons could be fabricated for testing. These welded joints were vacuum tested by JLT's technicians prior to use to verify seam integrity. The joint with the stainless steel stiffening bars arrived fully fabricated and only required trimming for the test.

2.4 Bentonite

The bentonite used for this test program is identified as HYDROGEL 90 and was supplied to JLT from Wyo-Ben, Inc., Billings, Montana. A copy of the identification label and material specifications are included in Appendix B.

2.5 Tap Water

Tap water used for the work was provided by JLT as supplied to JLT by the Pennsylvania American Water Company.

3.0 MIX DESIGN

As part of the mix design, the soil was first tested to determine its physical properties, namely gradation (ASTM D-422) and specific gravity (ASTM D-854). Results are presented in Appendix B. The soil is classified as a brown silty sand (SP-SM) with a specific gravity of 2.65. The grainsize was used as a means to estimate the percent bentonite, on a dry weight basis, necessary to add to achieve the desired permeability. The specific gravity was used for various calculations such as the determination of void ratio, degree of saturation and pore volume.

As originally proposed, it was decided to use a high slump backfill to prevent the material from arching in the narrow cutoff trench. Consequently, the mix design was focused on creating a suitable backfill with a high slump of approximately eight (8) inches. The mix design was performed as follows.

Based on our evaluation of the grainsize curve, it was estimated that about 3% bentonite would be required to achieve a permeability of about $1x10^{-7}$ cm/sec. Therefore, we elected to prepare 2, 3 and 4% bentonite content (by dry weight basis) mixes to span this initial estimate.

HYDROGEL 90 bentonite was selected based on JLT's experience with this product and its availability to Horizontal Technologies. The bentonite was prepared in slurry form with tap water using a standard shear mixer per API standards to create a bentonite fluid slurry for mixing with the on-site sand sample. The results of the basic physical properties of these slurries were:

Mixture % Bentonite	Density (g/cc)	Marsh Funnel (sec)
2	1.02	35
3	1.03	37
4	1.04*	40

* Slightly less than 1.04

Each mix was then blended with the on-site sand to create a test backfill mix with a suitable slump (≈8 in.) and consistency for the project having a bentonite content (by dry weight basis) of 2, 3, and 4%.

% Bentonite	Mix Slump (inches) (ASTM C-143)
2	8-
3	8
4	8+

Note: ***Due to the narrow width of the trench, a high slump backfill was selected for the design to preclude the possibility of side wall arching.***

Samples of these mixes were then placed in a Trautwein rigid wall slurry forming device and allowed to consolidate under an effective pressure of 6 psi for 24 hours. The formed samples were then removed and the weight, height and diameter were recorded. The sample was then placed in a flex-wall permeability device (ASTM D-5084) and allowed to consolidate under the following pressures.

Cell Pressure	=	50 psi
Headwater	=	42 psi
Tailwater	=	38 psi

The systems were then monitored until the following parameters were achieved.

Volume Change	=	0
Inflow	=	Outflow
Skempton's B-parameter	≥	0.96

Results of these three (3) flex-wall permeability tests using tap water as the mix water and permeant are presented in Appendix C. The results are plotted on Figure 1 and summarized below.

Percent Bentonite	Permeability (cm/sec)
2%	1.38×10^{-7}
3%	9.22×10^{-8}
4%	1.53×10^{-8}

Based on these results, it was determined that a bentonite content of approximately 3.5% would have been satisfactory to achieve a permeability $\leq 1 \times 10^{-7}$ cm/sec. However, not knowing the variation in material characteristics (principally the grainsize consist of the material) along the entire trench, it was concluded that a 4% bentonite content would be a more conservative design recipe for the backfill.

To reverify this mix, a second independent batch with 4% bentonite (by dry weight basis) was prepared and the material retested. The results of the verification test are also presented in Appendix C. The permeability of the verification mix was 1.98×10^{-8} cm/sec. Once comfortable with the performance of the design mix with 4% bentonite and tap water, the design mix was finalized for EPA 9100 compatibility testing.

4.0 EPA 9100 COMPATIBILITY TEST

A third batch of 4% bentonite mix was prepared using on-site sand and tap water, and this sample was also placed in the Trautwein rigid wall cell for forming and then into the Boart Longyear flex-wall permeability device. The sample was allowed to consolidate under the following pressures.

Cell Pressure	=	50 psi
Headwater	=	42 psi
Tailwater	=	38 psi

This yielded a gradient of 30 across the sample. The system was monitored until the following parameters were achieved.

Volume Change	=	0
Inflow	=	Outflow
Skempton's B-parameter	≥	0.96

A schematic of the compatibility testing equipment configuration is presented on Figure 2. On September 5, 1996. equilibrium conditions were fulfilled using tap water as the permeant and the test was continued with tap water until September 13, 1996 when the final baseline permeability with tap water as the permeant was determined ($k=2.68 \times 10^{-8}$) cm/sec. On September 13, 1996, the unit was converted to accept the 50:50 mix of site water using the system shown on Figure 2. This commenced the start of EPA 9100 compatibility testing.

Prior to this testing, the initial dimensions and weight of the sample were recorded. Using the weighted specific gravity (SpG = 2.68) of the combined soil (SpG = 2.65) and bentonite (SG = 2.75), the estimated initial pore volume of 140 cm^3 was computed. This was the pore volume used to compute the pore volume of liquid that entered the sample. Calculations are presented in Appendix D.

At periodic intervals. the flow, elapsed time and temperature of the water were recorded and the permeability and pore volume computed based on these original dimensions of the sample. The results are plotted versus elapsed time on Figures 3 and 4. On the 56th day, JLT was instructed to increase the gradient to about 50 to accelerate the test. To achieve this gradient, the pressures were set as follows using the initial dimensions of the sample to establish the gradient.

Cell Pressure	=	50 psi
Headwater	=	43.1 psi
Tailwater	=	36.9 psi
Gradient (Becomes)	=	50.18 based on initial dimensions

By inspection of the data plot (Figure 3), the fluctuation in the permeability plot between day 56 and day 66 is a reflection of this gradient change. The sample also consolidated with a 0.1 ml volume change which we deemed insignificant. Approximately 10 days were required (as expected) for the sample to reachieve equilibrium. The test continued until 3+ pore volumes of site water entered the sample based on the initial calculation of pore volume (140 cm^3). As a matter of note, it is assumed the first pore volume of site water displaced the tap water fluid in the sample, and that the first and second pore volume ultimately passed through the sample, leaving the third pore volume of site water in the sample at the time of test termination. Individual data reductions for each point on these curves (Figures 3 and 4) are presented in Appendix E.

Once the system was disassembled, the final dimensions, density and moisture content were determined and the final permeability and gradient were computed based on these final dimensions for the last data point. These results are presented in Appendix E and summarized below.

DAY 98 FINAL PARAMETERS	
Permeability	$2.45x10^{-8}$ cm/sec
Final Height	3.24 in.
Final Diameter	2.68 in.
Final Moisture Content	19.98%
Final Dry Density	114.5 pcf
Actual Final Gradient	52.81

Using these final measurements, the actual pore volume of the sample during the test was determined and the corrected pore volume vs. time and permeability vs. time were replotted for the entire test. Calculations are presented in Appendix D. These adjusted final pore volume flows and permeability curves are presented on Figures 5 and 6.

5.0 GEOMEMBRANE SEAM TESTING

To evaluate the performance of the hydrophilic seal in the geomembrane joint, three (3) 12-inch diameter specimens were prepared with the joint oriented along the diameter of the specimen. The joints were fitted with the hydrophilic rod and placed in a 12-inch diameter rigid wall test apparatus. Figure 7 shows a cross section of the joint and Figure 8 shows a schematic of the test apparatus. The circular specimen edge adjacent to the test chamber was sealed with a silicone seal and bitumastek joint sealer to prevent side wall leakage.

For one sample, 2 to 3 inches of tap water was placed on the upper side of the specimen to serve as a control sample. The two (2) other samples were covered with 2 to 3 inches of the 50:50 site water as the test samples.

A 5 psi pressure was applied to each of the water surfaces while the under side of the specimens were allowed to drain to atmosphere into a collection system. This 5 psi pressure on all three (3) samples was applied from August 15, 1996 until August 19, 1996 (4 days). No leakage was obseved from any of the test units.

On August 19, 1996, the pressure was increased to 10 psi until August 26, 1996 (7 days). Again, no leakage was observed.

On August 26, 1996, the pressure was increased to 15 psi and remained at this pressure until September 17, 1996 (21 days). Again, no leakage was observed through any of the specimens.

On that date, JLT was instructed by Horizontal Technologies to terminate testing of the specimen using tap water and to terminate one test specimen using the site water. The last site water test continued until December 19, 1996 (a total of 114 days at 15 psi). Once again, no leakage occurred through the system. At this point, Horizontal Technologies requested that the pressure be increased to determine if leakage would occur at higher pressures. The applied pressure was increased in 5 psi increments for a period of 48 hours (20 psi, 25 psi and 30 psi). At 30 psi, the seal adjacent to the edge of the sample failed. No leakage occurred through the joint. A photograph of this test sample cross section and a photograph of the hydrophilic seal before and after free swell hydration are presented in Appendix F.

The prefabricated seam with the stainless steel stiffening rods was also subjected to seam testing similar to the first specimens. A section of this specimen is presented on Figure 7A. The specimen was fitted into the test chamber and 2 inches of the 50:50 site water was placed over the specimen under a 2 psi load for a period of two (2) days to hydrate the system. It is noted that no leakage occurred during this test period. A 15 psi pressure was then applied and held at this level for ten (10) days. During this period, no leakage occurred and the system was disassembled.

6.0 CONCLUSIONS

Our conclusions, based on the results of this testing program, are summarized herein.

6.1 Mix Design and Compatibility

The 4% HYDROGEL 90 bentonite content (by dry weight basis) design mix selected for this project demonstrated a permeability of about $2x10^{-8}$ cm/sec with de-aired tap water as the permeant for both the original design mix and verification mix. When this mix was exposed to the 50:50 mixture (50% No. 3 groundwater and 50% No. 16 groundwater) of site groundwater per EPA 9100 protocols, the long term permeability averaged $3.5x10^{-8}$ cm/sec. This long term EPA 9100 test included 98 days of exposure and the entrance of 4.01 pore volumes of permeant fluid with about 3.01 pore volumes actually passing through the sample. During this 98 day period, the permeability remained consistent with normal fluctuations between data points which can be attributed, at least in part, to typical temperature fluctuations in the laboratory and the inherent accuracy of the equipment.

There was no evidence found in the data to suggest that the site groundwater had an adverse affect on the material's hydraulic conductivity properties under these conditions.

This design is predicated on the thorough mixing of the materials and does provide some allowance for soil variability. Should the field Construction Qaulity Assurance

(CQA) testing of the sand show gap graded materials. more poorly graded materials or the percent passing the #200 sieve below 6%. verification hydraulic conductivity performance tests should be performed to reverify the design mix performance.

It is assumed the Designer/Certifying Engineer has established a CQA testing program for the project which includes, as a minimum, the following:

- Periodic grainsize analysis of the sand (ASTM D-422)
- Periodic sampling of the insitu backfill materials for gradation (ASTM D-422) and hydraulic conductivity (ASTM D-5084)
- Field Slump Testing (ASTM C-143)

6.2 <u>Geomembrane Seam Test</u>

Throughout the test using differential pressures of 5. 10 and 15 psi across the seam, there was no leakage observed through the geomembrane joint or through the rivetted stainless steel bar joints. This data demonstrates that the hydrophilic rod did expand when exposed to site water and did create an effective hydraulic seal in the joints to prevent the transport of fluid through the joint. There was no evidence found to suggest that the site water had an adverse affect on the hydrophilic seal.

Sincerely,

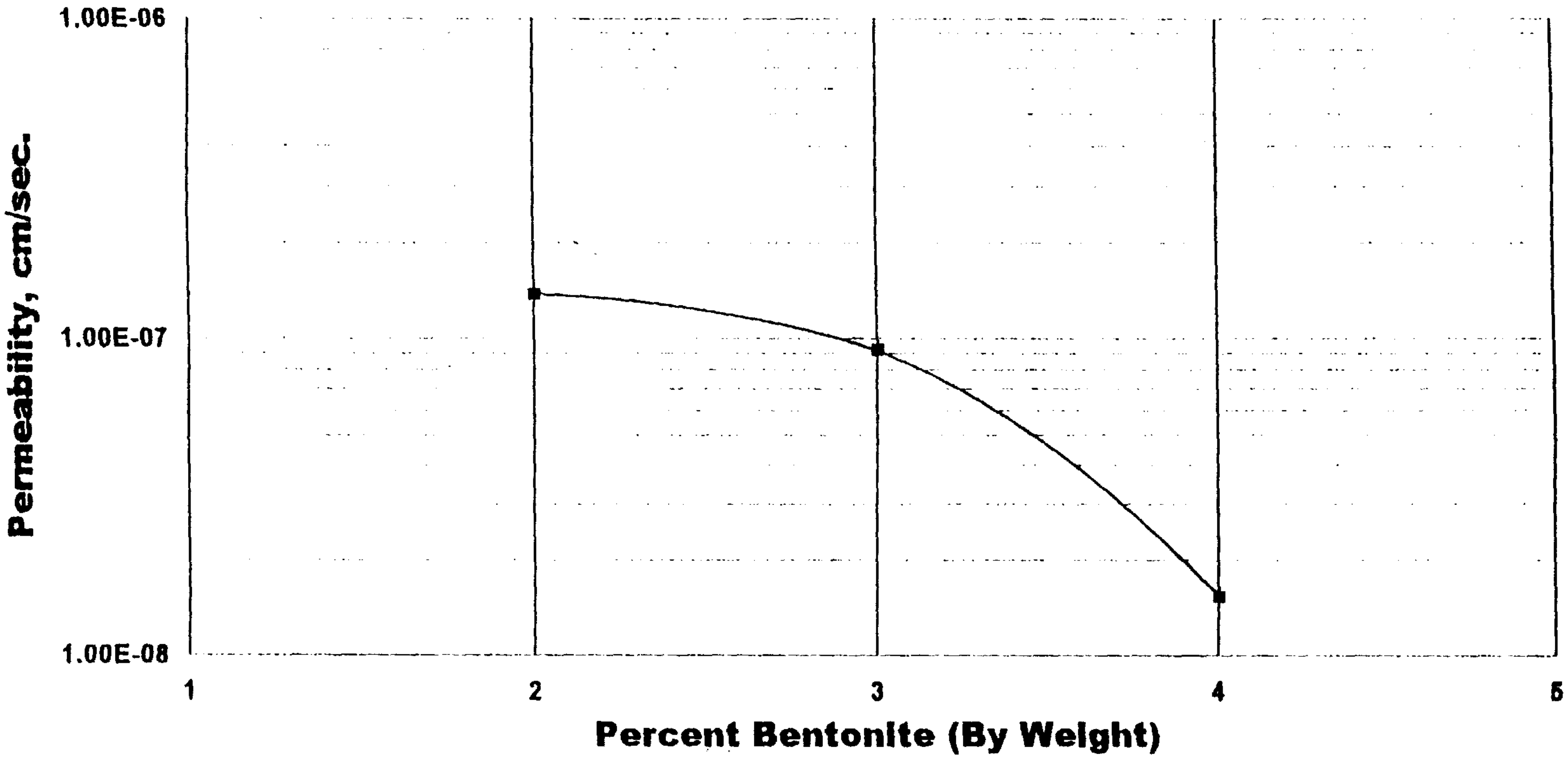
J&L TESTING COMPANY, INC.

John Boschuk, Jr., P.E., BEP
Technical Consultant

Enclosures
JB/rdg
\wpwin60\letter\9727

FIGURE 1
PERMEABILITY VS % BENTONITE

MIX DESIGN RESULTS
AMERICAN CHEMICAL NPL SITE BARRIER WALL



FLEX-WALL SOIL/FLUID COMPATABILITY APPARATUS SCHEMATIC

EPA 9100 / ASTM D-5084

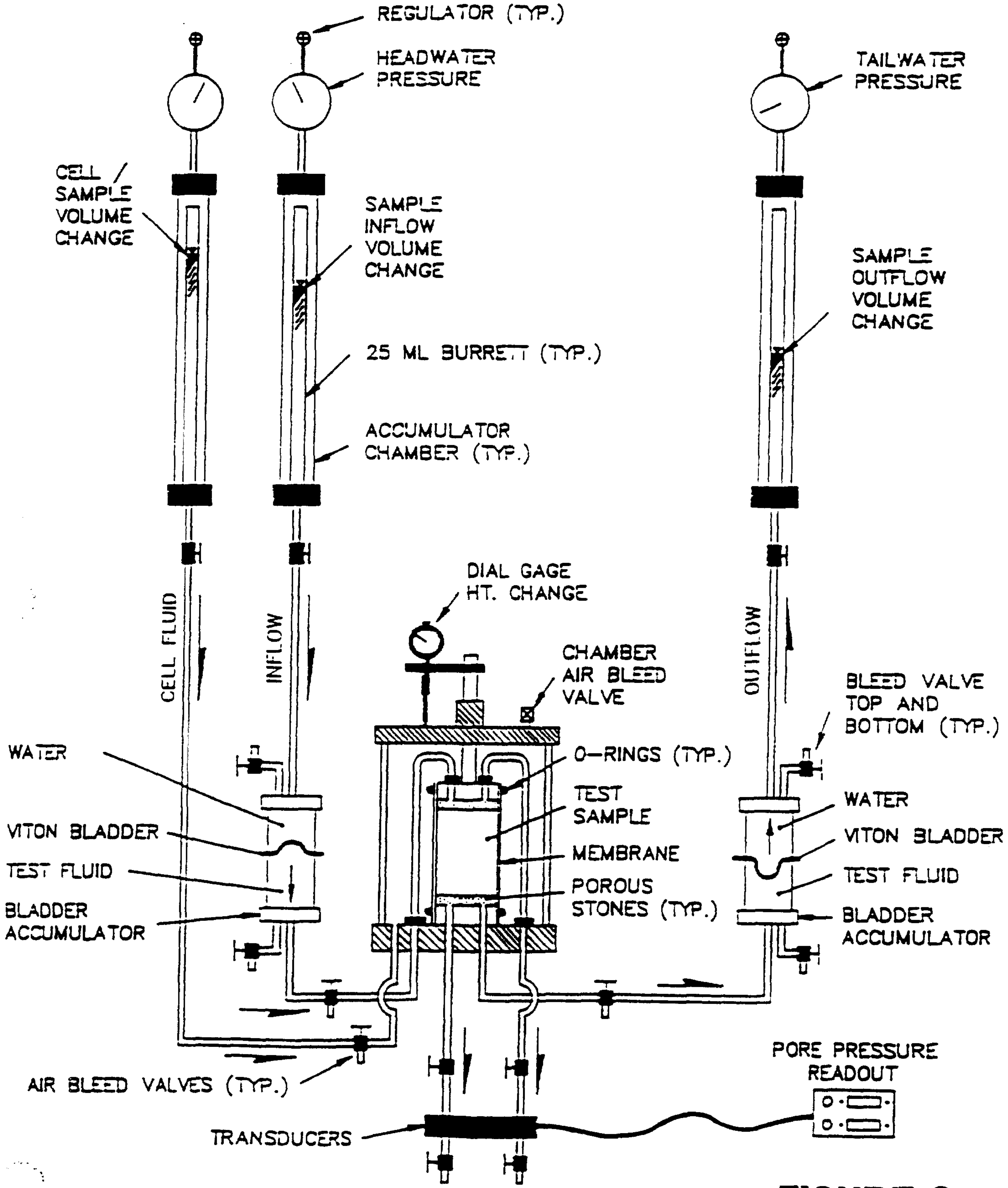
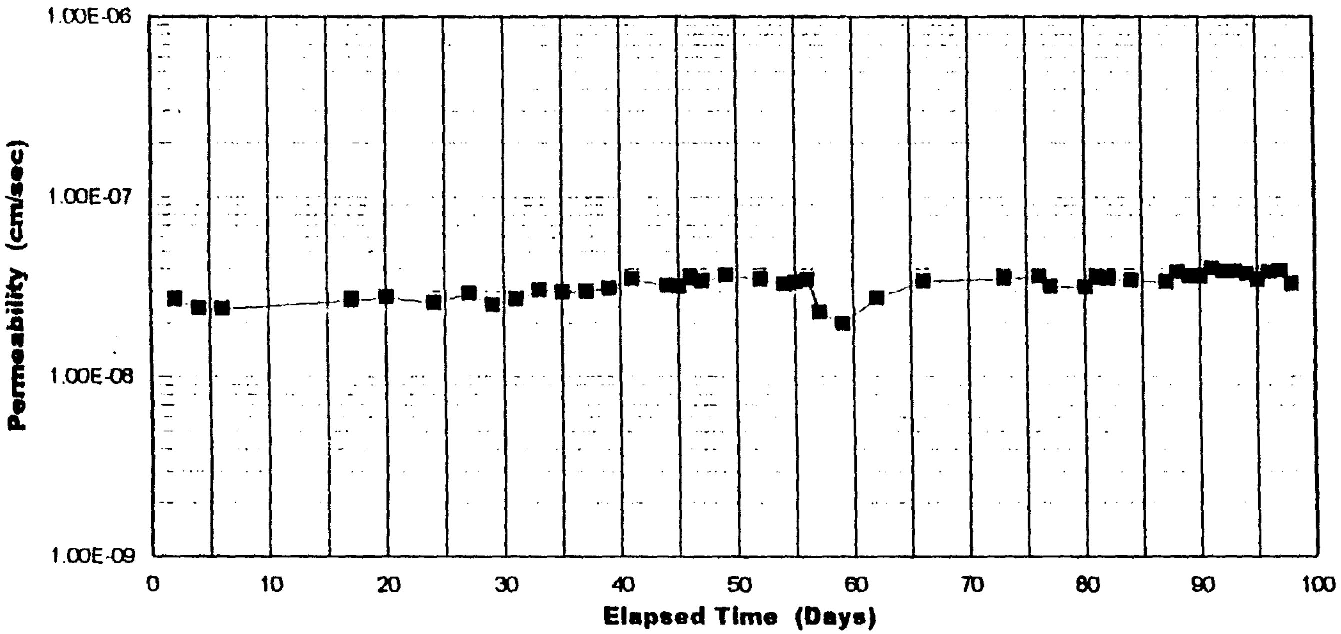


FIGURE 2

J & L Testing Company, Inc.

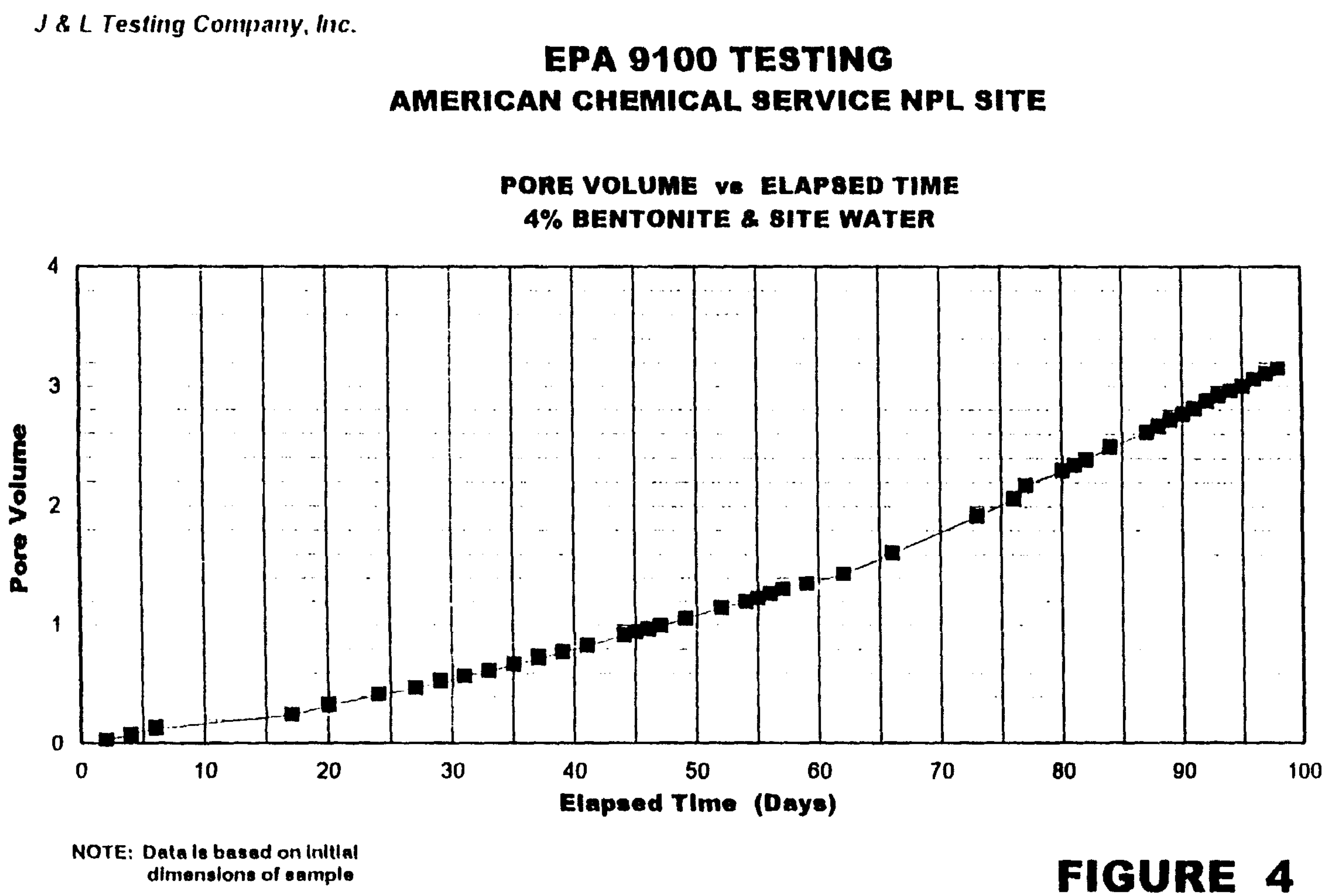
EPA 9100 TESTING
AMERICAN CHEMICAL SERVICE NPL SITE

PERMEABILITY vs ELAPSED TIME
4% BENTONITE & SITE WATER



NOTE : Data is based on initial dimensions of sample

FIGURE 3



J & L Testing Company, Inc.
EPA 9100 TESTING
AMERICAN CHEMICAL SERVICE NPL SITE
PORE VOLUME vs ELAPSED TIME
4% BENTONITE & SITE WATER
Pore Volume
0
1
2
3
4
0
10
20
30
40
50
60
70
80
90
100
Elapsed Time (Days)
NOTE: Data is based on initial dimensions of sample

FIGURE 4

EPA 9100 TESTING

AMERICAN CHEMICAL SERVICE NPL SITE

PERMEABILITY VS ELAPSED TIME
4% BENTONITE - SITE WATER

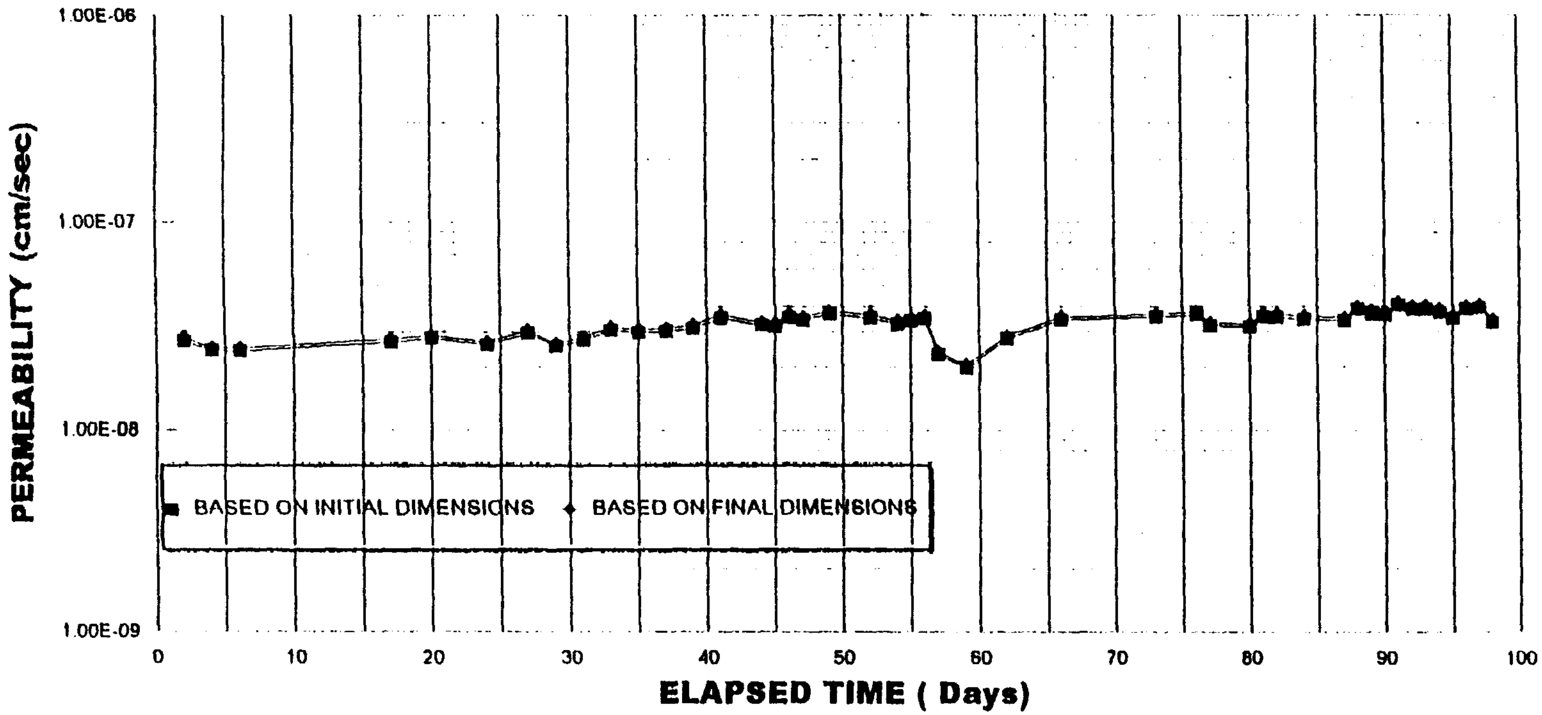


FIGURE 5

J & L Testing Company, Inc.

EPA 9100 TESTING
AMERICAN CHEMICAL SERVICE NPL SITE

PORE VOLUME VS ELAPSED TIME
4% BENTONITE - SITE WATER

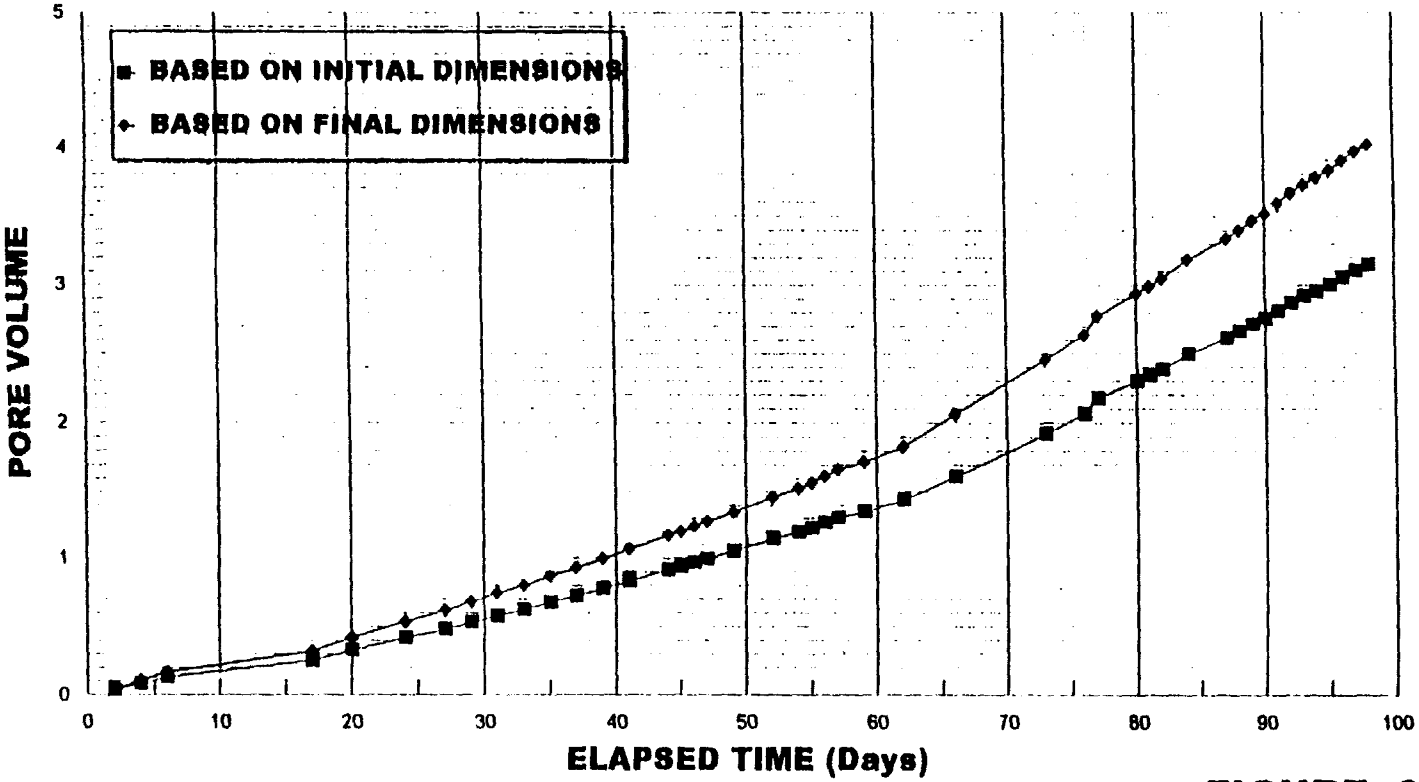
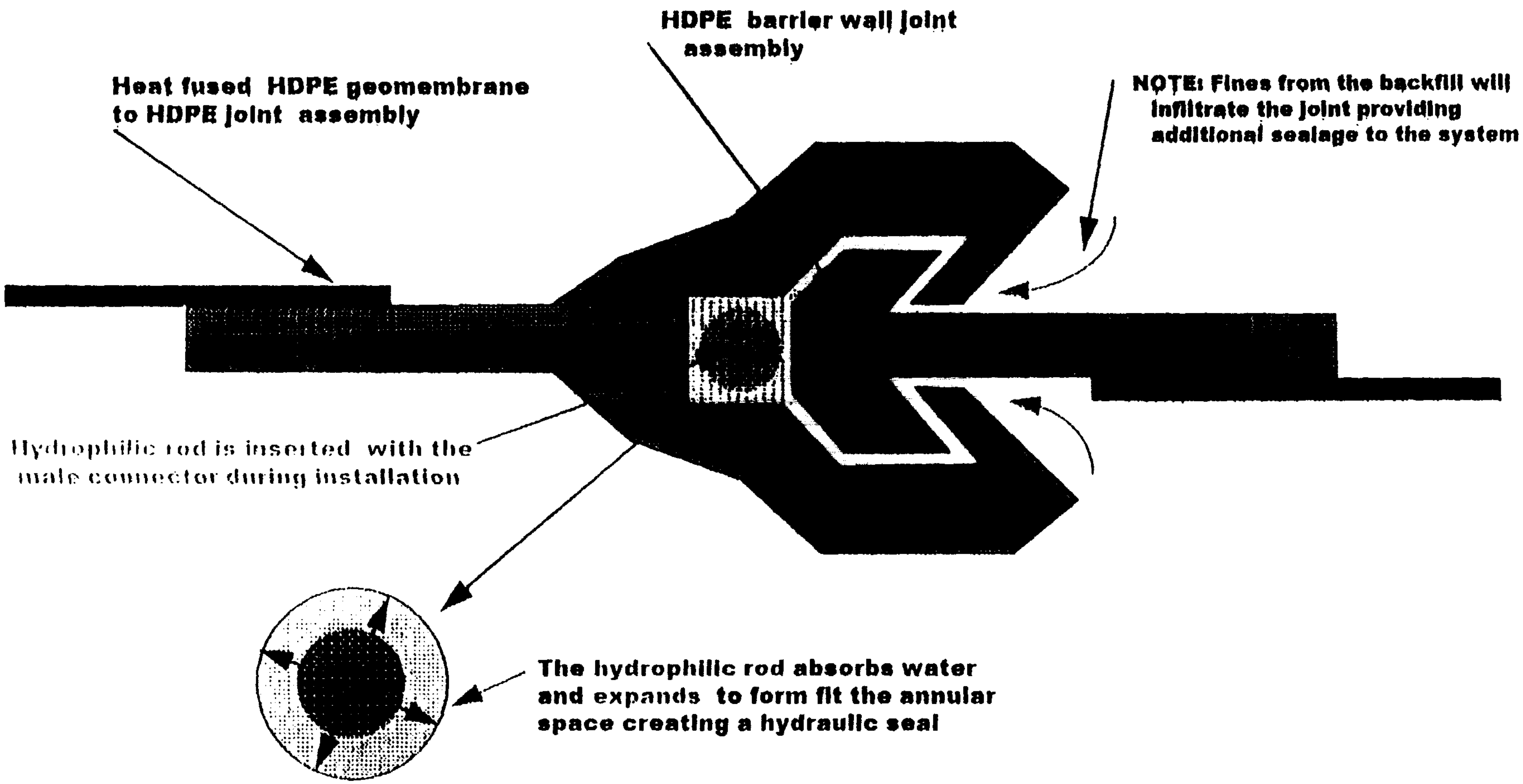


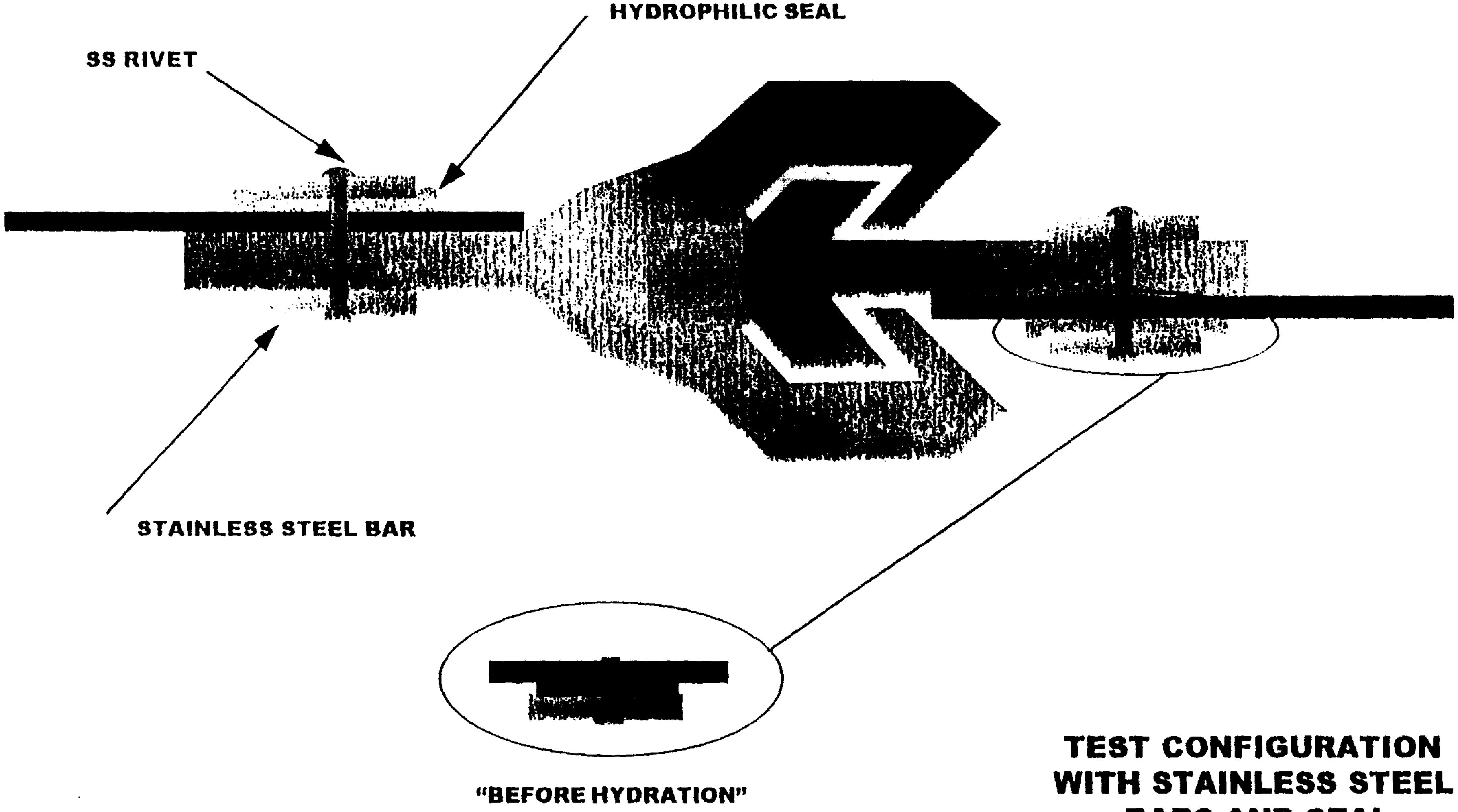
FIGURE 6



CROSS SECTION OF HDPE BARRIER WALL JOINT AND HYDROPHILIC SEAL

J & L Testing Company, Inc.

FIGURE 7



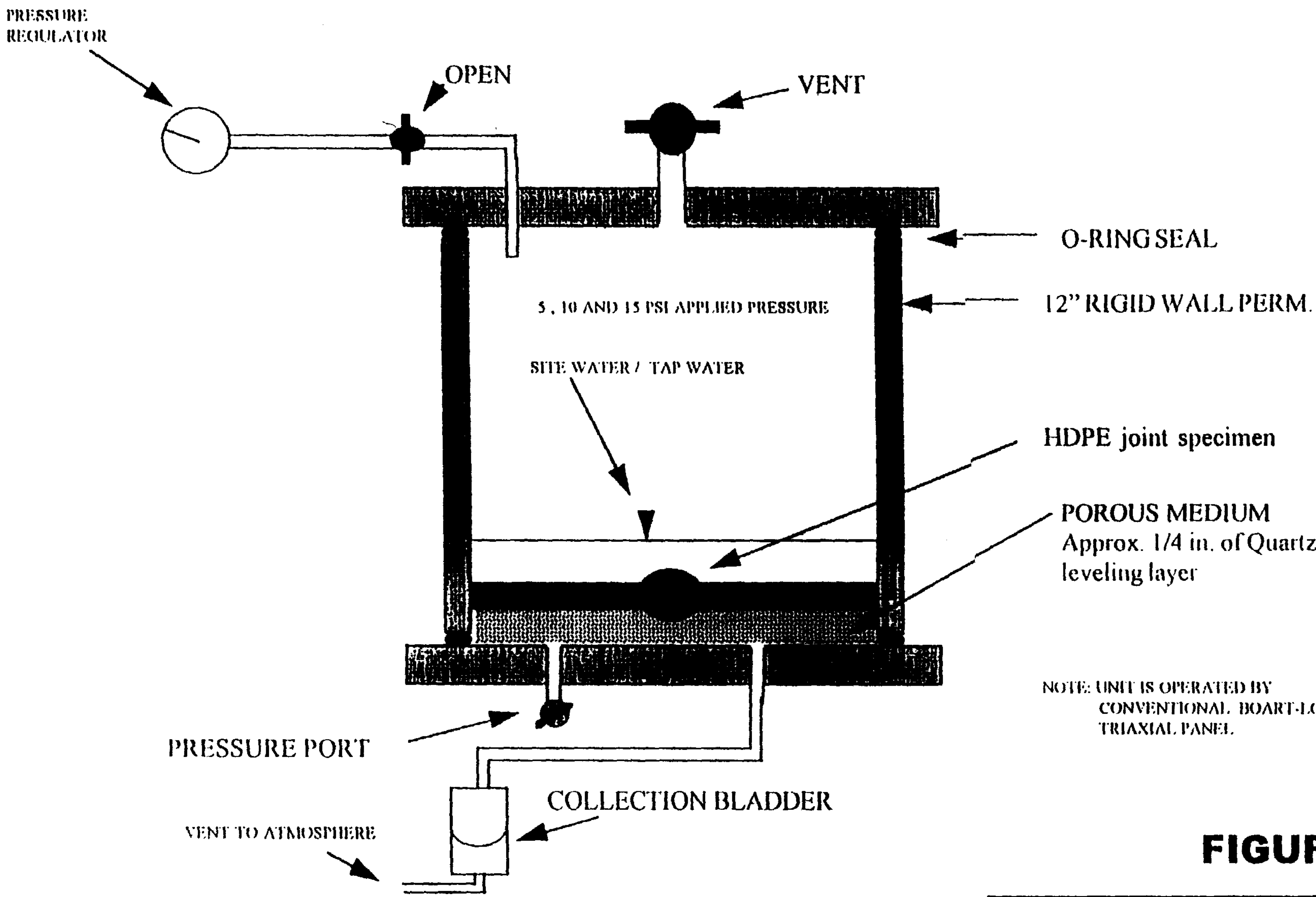
TEST CONFIGURATION WITH STAINLESS STEEL BARS AND SEAL

J & L Testing Company, Inc.

FIGURE 7A

J & L Testing Company, Inc.

12" RIGID WALL PERMEAMETER FOR GEOMEMBRANE JOINT TESTING



NOTE: UNIT IS OPERATED BY CONVENTIONAL BOART-LONGYEAR TRIAXIAL PANEL.

FIGURE 8